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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

This Issue

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PASSENGER CAR TRENDS AFFECTING FUELS AND LUBRICANTS

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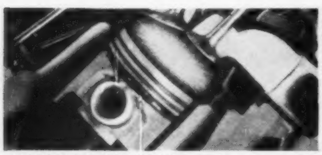

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Passenger Car Trends Affecting Fuels and Lubricants

WHAT does the passenger car mean to America? At the turn of the century, it was hardly more than a curiosity with a conviction shared by many that it would never become a reliable mode of transportation. For many years now, this conviction has been proven false and today, the passenger car is an important necessity to our social and economic lives.

A great many figures have been quoted at times to emphasize the tremendous magnitude of the passenger car industry. These have included such examples as millions of cars produced and/or registered and aggregate horsepower represented by these vehicles. While such figures are at times staggering, a much closer example is at hand. Let anyone take a Sunday drive on our crowded roads and he is soon forcibly impressed with the fact that passenger cars are big business. Obviously, every passenger car produced must be fueled and lubricated and while the volume of petroleum products used in a single car is relatively small, the overall consumption of all cars is enormous.

One major supplier of petroleum products, with considerable interest in the fuel and lubricant requirements of passenger cars, strives to keep abreast of all new automotive developments. By so doing, it hopes to have new products ready when demanded by new or increased severity requirements of the automotive industry. To accomplish this objective, it adopted a policy in the early 1930's whereby a number of new cars of different makes and models are purchased each year for performance testing and observation of their fuel and lubricant requirements. This has produced a valuable record from which overall trends in the automotive industry can be discerned. The material in this article has been drawn primarily from this source and from others as necessary. While a study could have been made of the past twenty-five years, it was felt that data prior to World War II would have been only of academic interest. This article is therefore limited to postwar trends and specifically those of the past ten years from 1947 to 1957.

MANUFACTURING TRENDS

The past ten years have seen tremendous advances in the automotive industry, both from the standpoint of improved mechanical design as well as new mechanical innovations. These have been reflected each year in the manufacturers' specifications.

Brake horsepower is one specification of major interest due to its considerable effect upon virtually all components of the car. Its trend is shown in Figure 1. This curve will be typical of many others

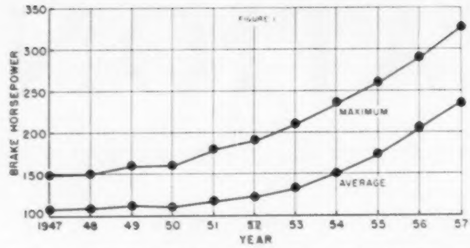


Figure 1 — Average and maximum engine brake horsepower rating.

where the maximum figure for any given year is presented as well as the overall industry average. Of most interest here is the fact that within the past decade, horsepower has more than doubled and as yet, has shown no sign of levelling off. This increase has been accompanied by a similar trend in torque, Figure 2, although here the average change has been only slightly over 50%. The increases noted have *not* been accomplished by merely expanding engine

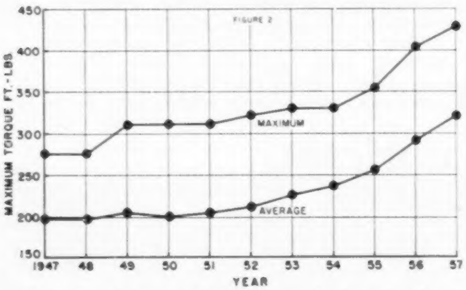


Figure 2 — Average and maximum engine torque rating.

physical size since Figure 3 denotes a consistent improvement in brake horsepower per cubic inch of displacement. In addition, Figure 4 shows that available horsepower has grown considerably in relation to car weight.

The next figures illustrate some of the factors contributing to the horsepower rise. In Figure 5, the recent trend toward the very compact V-8 engine is apparent while Figure 6 shows an increase in displacement of approximately 25%.

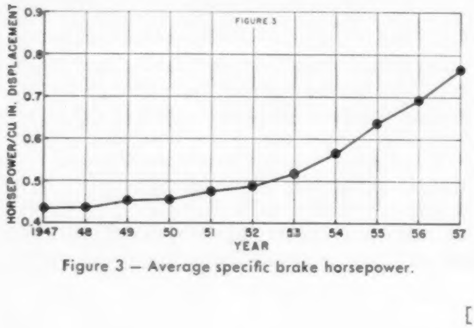


Figure 3 — Average specific brake horsepower.

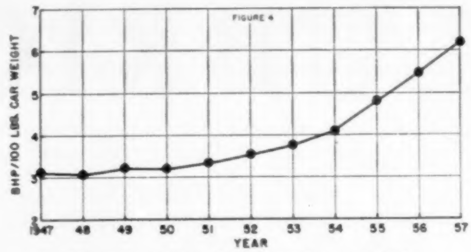


Figure 4 — Ratio of horsepower to car weight.

As illustrated in Figure 7, compression ratio has demonstrated a consistent rise from an average of 6.7 to approximately 9.0 with certain production models being as high as 10:1. As expected, brake mean effective pressure (BMEP) has also risen as indicated in Figure 8.

Engine speed has played a contributory role. In Figure 9, it may be seen that rated engine speeds

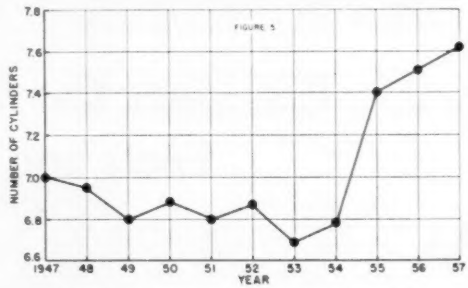


Figure 5 — Average number of engine cylinders.

in excess of 4500 revolutions per minute (RPM) are not uncommon today as compared to about 3600 RPM ten years ago. While this represents approximately a 25% increase in engine RPM, a corresponding increase in piston speed has not been noted. This is shown in Figure 10 where the change has been about 10%. An explanation of this may be found in Figure 11 where a trend toward reduced stroke and increased bore is obvious.

In addition to the foregoing, there have been a number of new mechanical features that have found excellent acceptance in the automotive field as illus-

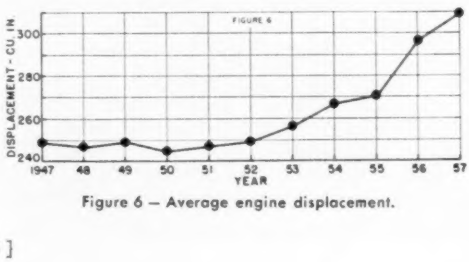


Figure 6 — Average engine displacement.

trated in Table I. Discussion of a number of these will be made later.

PERFORMANCE TRENDS

As might be expected, the foregoing manufacturing trends have been reflected in the performance characteristics of passenger cars. A number of these have been selected for discussion and have been categorized for convenience of presentation in the following section.

The data were obtained while operating on a chassis dynamometer of the type shown in Figure 12. Ambient air temperature unless otherwise specified was 80°F. Full throttle data were taken at wide open throttle in the highest available driving gear, with a few exceptions to be explained later. Level road data were obtained by first observing the vehicle's level road traction requirements on the road with inductive strain gage torque wheels and/or mani-

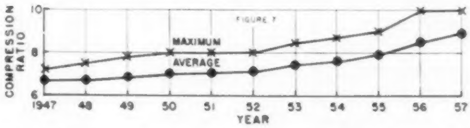


Figure 7 – Average and maximum engine compression ratio.

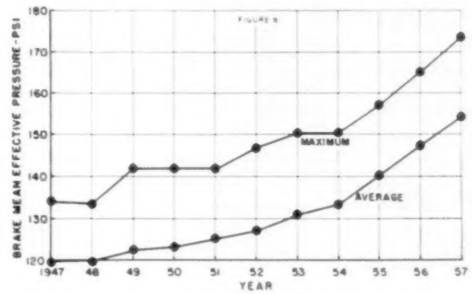


Figure 8 – Average and maximum brake mean effective pressure.

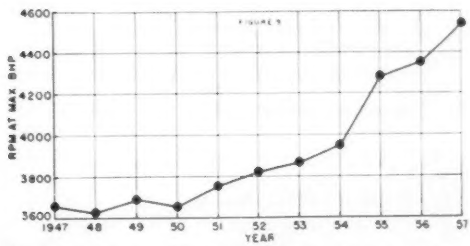


Figure 9 – Average engine revolutions per minute at maximum brake horsepower rating.

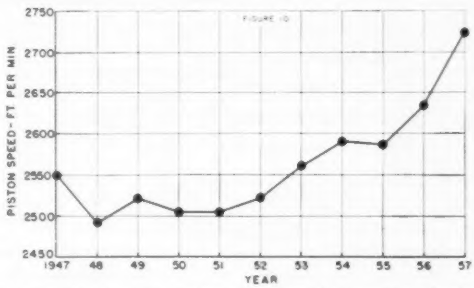


Figure 10 – Average engine piston speed at maximum brake horsepower rating.

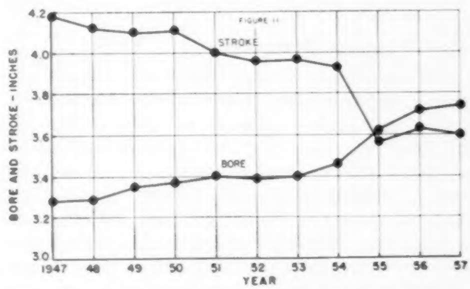


Figure 11 – Average engine bore and stroke measurements.

TABLE I

MECHANICAL INNOVATIONS

	NUMBER OF MANUFACTURERS SUPPLYING IN PRODUCTION CARS										
MECHANICAL FEATURE	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957
AUTOMATIC TRANSMISSIONS	4	6	8	12	17	17	17	17	19	19	19
HYDRAULIC VALVE LIFTERS	3	3	5	6	7	8	9	9	14	16	14
OVERHEAD VALVE V-8 ENGINES			2	2	4	6	8	10	17	18	19
POWER STEERING					2	3	9	14	18	19	19
POWER BRAKES					2	3	5	10	15	19	19
AIR CONDITIONING							2	6	18	19	19
BALL JOINT SUSPENSION								3	5	5	13
TORSION BAR SUSPENSION									1	1	5
FUEL INJECTION											2

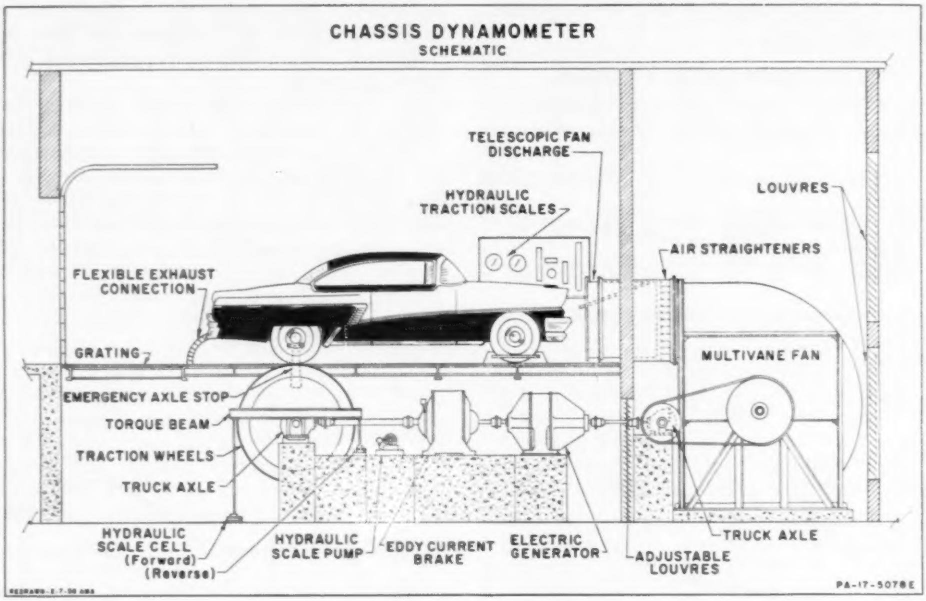


Figure 12 — Chassis Dynamometer.

fold vacuum instrumentation and subsequently reproducing these tractions on the chassis dynamometer.

Full Throttle Performance

Predictably, large and significant changes have been noted in certain of the full throttle performance characteristics. One of the most outstanding of these has been traction available at the rear wheels, Figure 13 showing an increase from 449 to 846 pounds or approximately 90%. This has also resulted in improved grade climbing ability as demonstrated in Figure 14 where we note that today's cars can overcome a grade of 22½% as compared to 12% in 1947. Both of these are, of course, natural outgrowths of the horsepower increase previously discussed.

The picture is not quite as bright when fuel economy is considered. In Figure 15, it may be seen that full throttle fuel economy has suffered a gradual decline of about 2.5 miles per gallon. This may be rationalized as being the result of larger engines and higher operating speeds. These larger and higher speed engines are somewhat more efficient than their predecessors, however, as is obvious from the next two figures. In Figure 16, a decrease in brake specific fuel consumption (BSFC) from 0.78 to

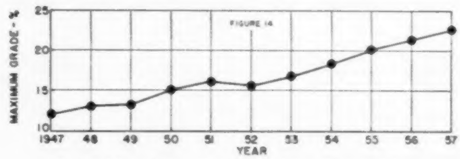


Figure 14 — Average measured grade capability.

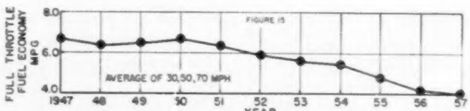


Figure 15 — Average measured full-throttle fuel economy.

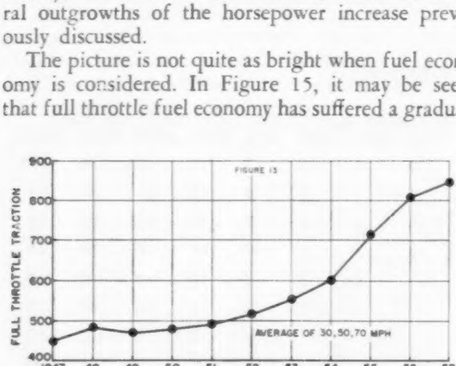


Figure 13 — Average measured full-throttle traction.

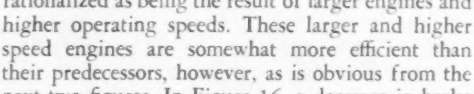


Figure 16 — Average measured full-throttle brake specific fuel consumption.

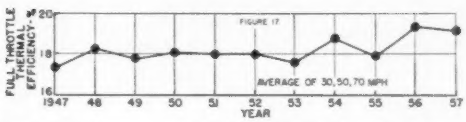


Figure 17 — Average measured full-throttle thermal efficiency.

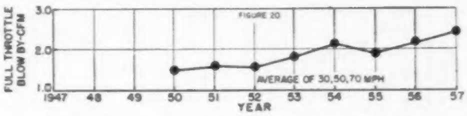


Figure 20 — Average measured full-throttle blowby.

0.71 pounds per brake horsepower hour may be noted while Figure 17 shows a gradual and concurrent increase in brake thermal efficiency from 17.4 to 19.2%. The values discussed are not consistent with those that might reasonably be expected from a dynamometer mounted engine, being higher for BSFC and lower for thermal efficiency. This is explained by the fact that all calculations were made on the basis of power delivered at the rear wheels of the car, rather than at the crankshaft.

Figure 18 is indicative of the trend in volumetric efficiency. The change in slope in 1954 and subsequent decline in efficiency appears unusual at first glance. However, a review of the manufacturers' specifications of the cars tested reveals that this is coincident with a relatively large rise in valve overlap. From 1947 until 1954, the test cars had shown a gradual increase in valve overlap from an average of 18 degrees to 30 degrees. However, in the last

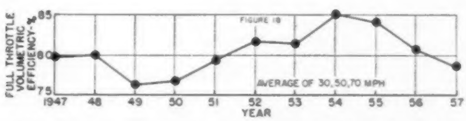


Figure 18 — Average measured full-throttle volumetric efficiency.

three years, this value has risen rather steeply to an average of 45 degrees.

Another pair of trends of interest, particularly to the oil industry, are those of crankcase ventilation and blow-by. Crankcase ventilation has undergone no significant change as demonstrated in Figure 19. But in contrast, Figure 20 shows that blow-by increased nearly one cubic foot per minute (cfm). This may be attributed in part to the general rise in compression ratio and BMEP observed earlier.

Level Road Performance

In level road performance work, fuel economy is of great interest. Figure 21 indicates that significant improvements were made during the early postwar period, probably associated with increasing numbers of the more efficient V-8 overhead-valve engines coming into prominence. During the past few years,

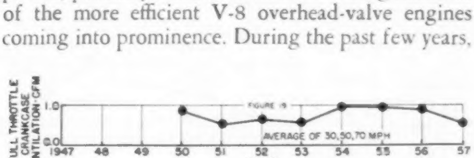


Figure 19 — Average measured full-throttle crankcase ventilation.

this improvement has been overshadowed by the influence of rising level road tractive requirements, resulting in some reduction in fuel economy. Figure 22 shows that thermal efficiency has shown a somewhat erratic but generally rising trend during the postwar period. Volumetric efficiency (Figure 23) on the other hand has been steadily decreasing during this period to about 70% of its 1947 value, indicating that for level road operation the newer engines are being operated with smaller throttle openings to supply the required power. Level road crankcase ventilation and blow-by rates are noted from Figures 24 and 25 to be at about the same level as they were in 1947.

Temperature History

The preceding discussion of performance has not included temperatures, which are an indication of operational severity. The temperatures observed at

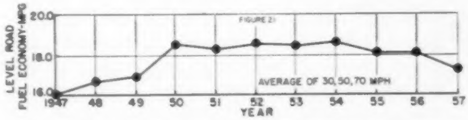


Figure 21 — Average measured level-road fuel economy.

key points in a vehicle are of vital concern to the manufacturer and to the fuel and lubricant supplier. Temperatures during the tests described were observed at about eighteen locations in the fuel, coolant, lubricating oil, air induction and exhaust systems.

In fuel systems, some of the more critical temperatures are those encountered from heat soak-back after a steady run. Some indication of the severity of this factor has been obtained by observing the maximum temperatures attained after shut-down following 60 MPH level road operation at an ambient air temperature of 100°F. Figure 26 shows the average intake manifold temperature, measured in the above manner, and the maximum observed for any single car each year. The percent of V-8 engine cars tested for the same years is also shown. It may

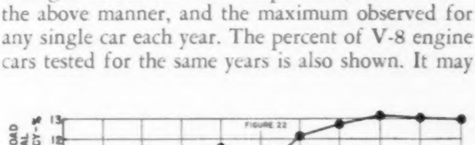


Figure 22 — Average measured level-road thermal efficiency.

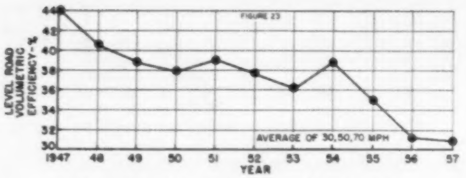


Figure 23 — Average measured level-road volumetric efficiency.

be noted that the average intake manifold temperature has decreased about 50°F over the past decade. This has undoubtedly been the result of the increasing number of V-8 engines tested, which have greater distances between intake and exhaust manifolds than did the older in-line engines. The foregoing is borne out in Figure 27, except for the year 1957, which shows the trend in carburetor bowl temperatures. The same reasoning applies to these temperatures although the differences observed are not as great as for the intake manifold. Fuel pump outlet temperatures are also shown in Figure 27 and are noted to be without any particular trend.

Because of various changes in the test procedure, it is not possible to give high load temperature data on a consistent basis over the ten-year period under

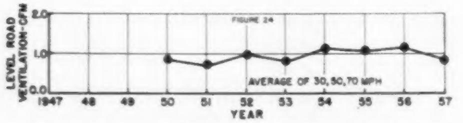


Figure 24 — Average measured level-road crankcase ventilation.

discussion. The closest common basis available is the use of equilibrium temperatures at 50 MPH, full throttle operation for the years up through 1955 and the use of equilibrium temperatures at 50 MPH, 10% grade for 1956 and 1957. This was the result of a decision in 1956 to abandon full throttle operation to equilibrium as being unrealistically severe for the testing of cars. Figure 28 depicts the trend in crankcase oil temperature on this basis. It may be noted that crankcase temperature has been steadily increasing, averaging at least 30°F hotter now as compared to 1947. The 1956 and 1957 temperatures break with the trend for the reasons explained but are still in the direction of becoming higher.

Figure 29 shows similar data for the transmission oil temperature, where the trend is noted to be quite

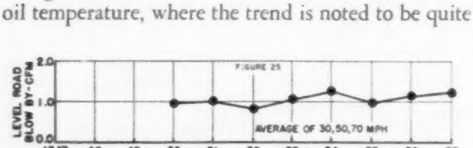


Figure 25 — Average measured level-road blowby.

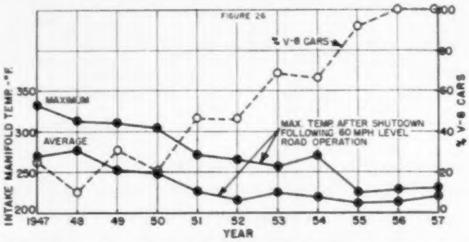


Figure 26 — Average and maximum measured intake manifold soak temperature after shutdown.

marked. Temperatures have increased considerably more than 100°F over the past decade. In certain cars it was considered necessary to terminate the test run before equilibrium conditions were obtained due to excessive transmission temperature rise. To protect against this, an arbitrary limit for transmission fluid temperature was set at 350°F. The encircled points represent those averages which include some temperatures that were not measured under equilibrium conditions. The 10% grade temperatures for the transmission also show a rising

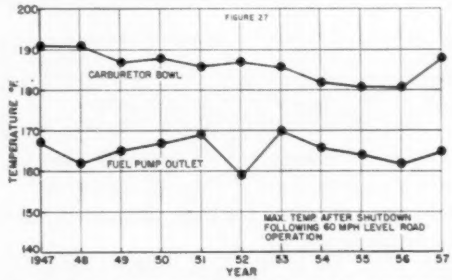


Figure 27 — Average soak temperatures after shutdown.

trend while at the same time breaking from the full throttle temperatures. As indicated by the encircled 10% grade points, some transmissions would have exceeded the 350°F temperature limit had the test been run to equilibrium.

Figure 30, the rear axle temperature plot, does not exhibit any particular trend. Many of the points shown are not at equilibrium because overheating of the transmission fluid prevented operation of the rear axle to equilibrium. The temperatures are therefore lower than they should be and it seems

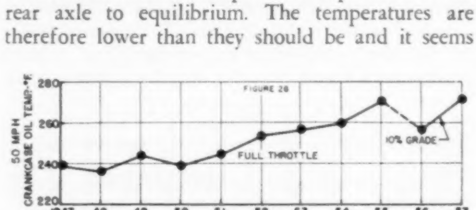


Figure 28 — Average crankcase oil temperature at 50 m.p.h.

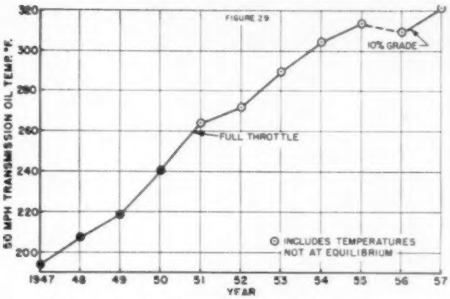


Figure 29 — Average automatic transmission oil temperature at 50 m.p.h.

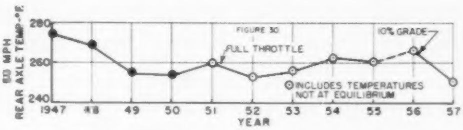


Figure 30 — Average rear axle temperature at 50 m.p.h.

likely, in view of the larger engines and greater power transmitted, that some increase in rear axle temperature has occurred although the data do not show it.

Performance of Non-Standard Models

In recent years, a number of manufacturers have made available higher output versions of their stock model engines. In some cases, these have represented a whole new engine, while in others, the changes have been accomplished through the use of modification kits. In either case, these non-standard vehicles are of interest, since they may frequently be interpreted as the forerunners of design modifications which will be incorporated in production cars. A number of these have been tested and their performance relative to their standard counterpart is shown in Table II. As noted, two major differences exist in most cases between the standard and non-standard models. These are an increase in compression ratio and the use of high lift cams.

From the data shown, certain generalizations may be stated. In every case, full throttle brake horsepower delivered at the rear wheels has increased, ranging from 2.2 to 11%. Consistent with this, a decrease in average volumetric efficiency up to 11.3% was noted for all but one of the cars. Overall, full throttle fuel economy exhibited no significant change. Some cars reflected a depreciation in level road fuel economy while others did not. This factor was dependent upon the overall individual design and was not influenced directly and solely by an increase in compression or the use of high lift cams.

Effect of Air Conditioning on Performance

A number of papers have been published on the effect of air conditioners on fuel requirements, but little or nothing is available to demonstrate their effect on performance. Since these units require power for their operation and since this power is derived from the car's engine it is reasonable to conclude that their operation should be reflected in the overall performance of the vehicle. Table III illustrates the magnitude of the performance penalty paid for the convenience of air conditioning. In

TABLE II

PERFORMANCE COMPARISON OF STANDARD AND NON-STANDARD PASSENGER CARS

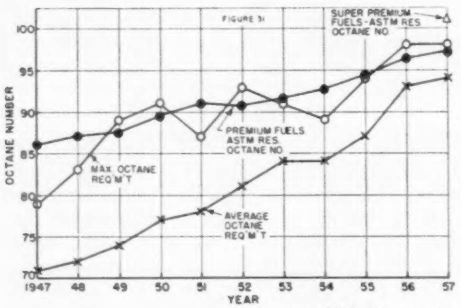
	AVERAGE OF 30, 50, 70 MPH FULL THROTTLE					LEVEL ROAD
	ENGINE RPM	TRACTION* LBS.	BRAKE HP*	VOLUMETRIC EFFICIENCY %	FUEL ECONOMY MPG	FUEL ECONOMY MPG
1955 CAR A						
STANDARD MODEL	2985	879	108.4	92.0	3.7	16.1
11:1 COMPRESSION RATIO	3012	883	110.8	80.7	3.8	17.6
1956 CAR B						
STANDARD MODEL	2609	793	100.0	85.4	4.1	19.4
12:1 COMPRESSION RATIO	2666	876	111.0	83.0	4.2	18.3
1956 CAR C						
STANDARD MODEL	2676	728	92.5	85.2	4.8	18.3
11:1 COMPRESSION RATIO - STD. CAMSHAFT	2694	795	101.3	78.1	4.6	17.4
11:1 COMPRESSION RATIO - HIGH LIFT CAMSHAFT	2686	792	101.0	78.9	4.3	17.9
1956 CAR D						
STANDARD MODEL	3165	783	96.9	73.8	4.9	16.8
HIGH OUTPUT-VERSION	2899	817	101.7	81.3	4.3	16.6

*MEASURED AT REAR WHEELS.

TABLE III

EFFECT OF AIR CONDITIONING ON PERFORMANCE

	FULL THROTTLE TRACTION-LBS. (AVG. 30, 50, 70 MPH)		LEVEL ROAD FUEL ECONOMY-MPG (AVG. 30, 50, 70 MPH)	
	AIR CONDITIONING		AIR CONDITIONING	
	ON	OFF	ON	OFF
1957 CAR A	818	840	15.6	16.3
1956 CAR B	727	760	15.4	17.1
1956 CAR C	725	755	16.6	18.1
1956 CAR D	775	783	15.6	16.8
1955 CAR E	862	895	15.1	16.2
1955 CAR F	747	762	14.9	15.7
1954 CAR G	603	608	14.9	15.5
1954 CAR H	697	733	17.7	19.6



Courtesy of Ethyl Corporation

Figure 31 — Average premium fuel octane versus average and maximum car octane requirement.

every case, the use of an air conditioner resulted in a reduction of power delivered at the rear wheels and a decrease in fuel economy. On a percent basis, these represent a loss in rear wheel traction of 1 to 5 percent and a concurrent depreciation in fuel economy from 4 to 10 percent.

EFFECTS ON FUELS AND LUBRICANTS

Up to this point, the discussion has dealt with the design and performance trends of the cars themselves. Many of the trends have shown that substantial changes have occurred in both design and performance. These have, of course, resulted in a number of modifications in the fuel and lubricant requirements of the vehicles.

Fuels

The one requirement which has received the most publicity over the past several years is that of fuel. In this category, anti-knock performance has been stressed most heavily as a result of a continuous rise in octane requirement of passenger car engines. Figure 31 depicts the trend in passenger car octane requirement as well as the accompanying trend in gasoline anti-knock quality. Here it may be noted that octane requirement has shown a steep and con-

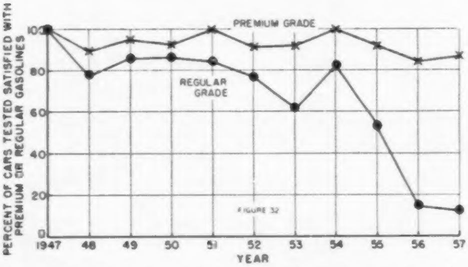


Figure 32 — Car octane satisfaction with premium and regular grade fuels.

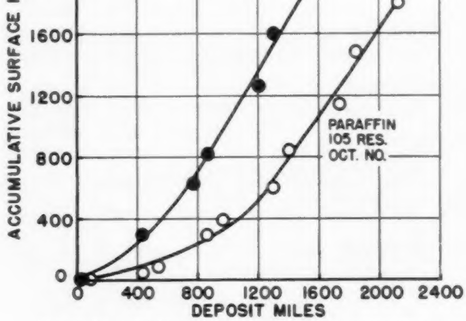


Figure 33 — Surface ignition versus fuel composition.

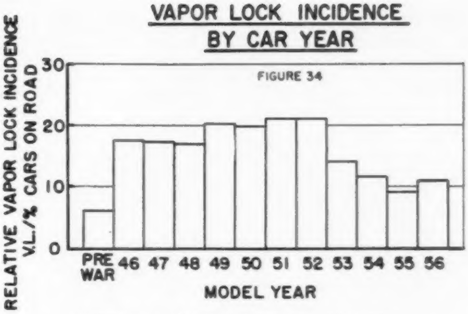


Figure 34 — Relative vapor lock incidence.

sistent increase over the past ten years. This is a natural result of such design factors as compression ratio, valve and ignition timing, carburetion, etc. which have led to today's high output engines. Also shown is the manner in which the anti-knock quality of fuels has kept pace with this requirement. From 1947 to 1957, octane requirement of the test cars purchased rose from 71 to 94, while in the same period, the ASTM Research octane number of premium gasoline increased from 86 to 97. While the majority of cars have been satisfied with premium grade gasoline, a small but increasing percentage have not. This is illustrated in Figure 32, where the trend since 1954 is quite apparent. Because of this, some petroleum companies have begun marketing a third or super premium grade of gasoline whose position in this situation is also shown in Figure 31. It should further be noted here that the number of cars satisfied with regular gasoline has declined sharply in these same three years.

Another fuel factor gaining prominence is surface ignition. As the compression ratio of passenger car engines has increased, octane requirement has also risen. This requirement has and is being satisfied by current commercial grade fuels. However, as compression ratios approach the order of 12:1, the engines become more susceptible to surface ignition. In fact, it appears that surface ignition requirement may eventually compete with octane requirement for first place in relative order of importance. Unfortunately, some of the components of commercial fuels which are most desirable for satisfying high octane requirements are those which have reduced resistance to surface ignition. It further appears that some of the best fuels known today might not be able to entirely eliminate surface ignition at the 12:1 compression ratio level. To illustrate these phenomena, Figure 33 shows cumulative surface ignition counts for two widely different fuels. These data were obtained from a 12:1 compression ratio engine installed in a current model car and operated on a simulated city-type driving schedule. One fuel had a moderate aromatic content while the second was a paraffinic stock; each contained 3 ml. TEL/gal. The former had an ASTM Research octane number of 106 while the second rated 105. Both fuels satisfied the spark ignition octane requirement of the engine. Note from the slope of these curves that there was no significant difference in surface ignition *rate* between the two in spite of the wide variation in composition. In both cases, surface ignition was not only observable with instrumentation, but was also clearly audible. The problem of surface ignition is gradually increasing in importance as compression ratio continues to rise and considerably more work will be required before a satisfactory solution to it is obtained.

No discussion of fuel requirements would be complete without examining the subject of vapor lock. Figure 34 shows the relative vapor lock tendency of various production year cars based on a survey made in the summer of 1956. The data were obtained by observing a large number of cars at various selected

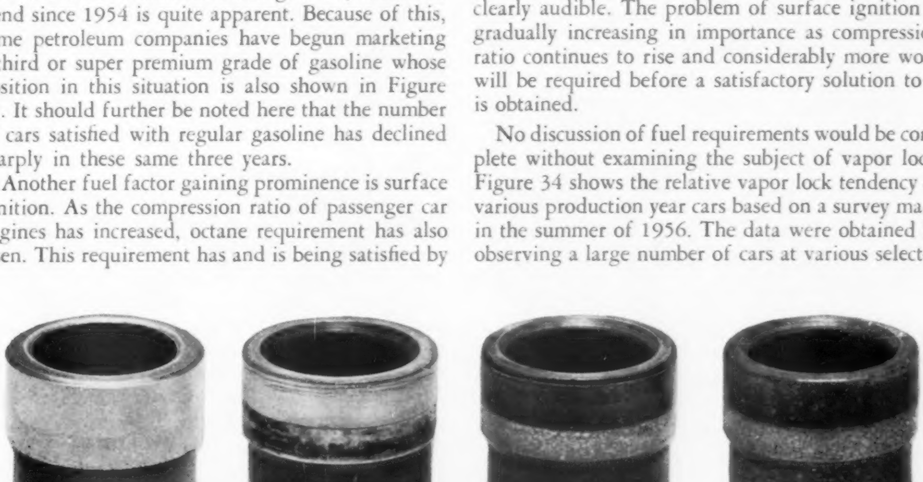


Figure 35 — Effect of oil detergency on hydraulic valve lifter deposits.

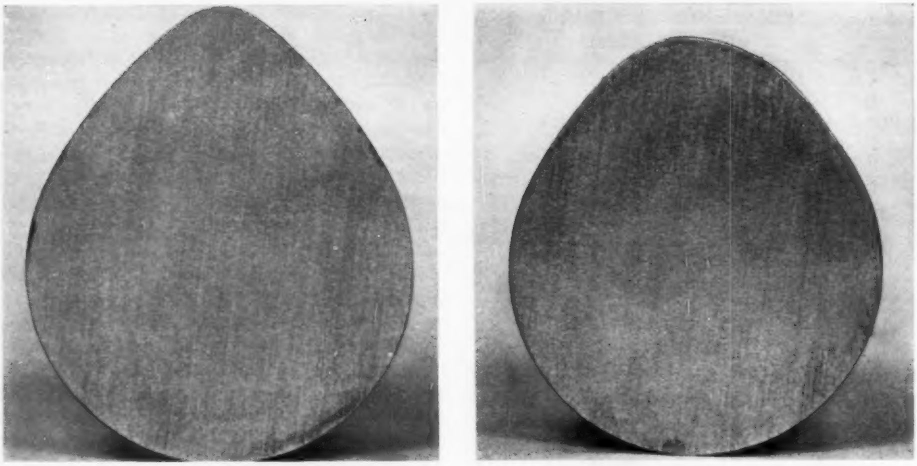
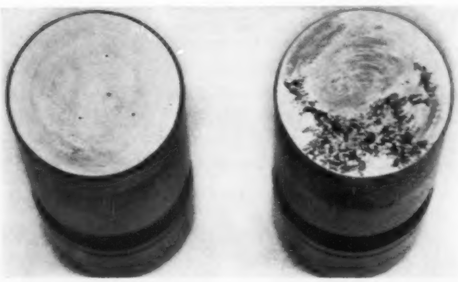


Figure 36 — Effect of oil quality on cam nose wear.

locations throughout the country. The "incidence rate" is the number of vapor locks observed for cars of a given model year divided by the percent of the total cars on the road that the model year represents. The data indicate that postwar cars, except for the past few model years, have nearly equal and relatively high vapor lock incidence rates. The prewar models observed had quite a low rate. Also of interest is the decrease in vapor lock incidence for the 1953 and newer cars. Based upon this and previous surveys, it is indicated that newer cars, which have fuel and coolant systems in good condition, have lower incidence rates than cars that are a few years older. In a previous survey, summer of 1952, it was noted that the newer cars, at that time, had lower rates than their predecessors and these same vintage cars in the later survey show a relatively high incidence, slightly higher than the early postwar models they surpassed in the 1952 survey.



Good oil Poor oil

Figure 37 — Effect of oil quality on spalling and wear of valve lifters.

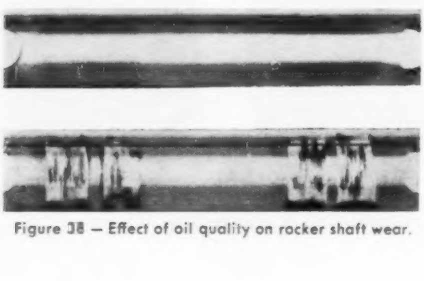


Figure 38 — Effect of oil quality on rocker shaft wear.

Crankcase Lubricants

Another petroleum product of considerable interest is the crankcase lubricant. This product has also been markedly affected by the preceding trends. The most significant contributor to its change in performance requirements has been the valve train section of the engine. Initially, the increasing popularity of hydraulic valve lifters created a demand for improved detergent characteristics of the oil. This improvement was a result of the close operating clearances within the lifters' mating parts where slight amounts of deposit caused lifter sticking and erratic, noisy engine operation. An example of the deposits formed and their location is illustrated in Figure 35. The lifters shown were obtained from a low temperature, light duty road test after 10,000 miles of operation. The one at the extreme left represents the benefits obtained with the use of high detergent type oils, while the others are indicative of the deposit-forming tendencies of non-detergent type oils.

As the speed and output of engines ascended, other valve train problems arose to increase the sever-

ity of motor oil requirements. These included cam lobe, cam follower and rocker arm shaft wear as well as cam follower and rocker arm shaft spalling and galling. While much could be and was done to solve these problems on a mechanical and metallurgical basis, it was also necessary for the oil to carry a share of the load by improvement of its anti-wear and load carrying characteristics. The improvements made in this direction are demonstrated in the next few figures. In Figure 36 are shown cam lobes from an accelerated laboratory engine test run for 24 hours at high speed, high temperature and with a 50 percent valve spring overload. Here again the effects of oil improvement are quite obvious since the cam on the left shows a negligible amount of wear with a good oil while the profile of the nose of the other cam has been almost entirely destroyed by a poor oil.

Figure 37 illustrates the effect of oil composition on spalling and wear of cam followers as obtained from simulated road operation on a laboratory engine. The three small dots on the left hand follower are impressions left by a hardness tester.

The last factor to be considered in the valve train is the rocker arm shaft assembly. Here again, higher loads and mechanical design have contributed to the severity of performance requirements of an oil. In Figure 38, the lower illustration depicts typical scoring and galling experienced in a 100-hour moderate speed, no load laboratory test with an inadequate lubricant while the upper picture demonstrates the almost total prevention of wear and galling gained from the use of a protective motor oil. Although the problem of valve train lubrication has at times been severe, mechanical design, metallurgical advances and oil improvements in recent years have now reduced it to insignificant proportions in the field.

Deposits, of course, represent another problem which is ever present and which must be considered in any discussion of this kind. Their formation is induced by all types of car operation with some operations being more severe than others. As national car registrations have increased, our road systems have become more and more congested. These factors together with the rapid growth of suburban areas have led to a greater number of cars being operated on a lower mileage per trip basis. This type of operation is most conducive to the formation of low temperature deposits and it has been necessary to work continuously to improve the low temperature deposit resistance of motor oils and fuels. Figures 39 and 40 are indicative of the advances made in this field. In Figure 39 are shown two pistons from a low temperature, moderate load and speed laboratory engine test where the improvement in low temperature deposit formation is obvious. The dirty piston on the right was obtained on a given fuel-oil combination, while the clean piston was the result of a run on the same fuel but with proprietary additives added to the oil. A similar comparison is disclosed in Figure 40 which shows two oil filter cartridges after 10,000-mile low temperature road tests. The left hand filter indicates the improvement in current motor oils as compared to the right hand one

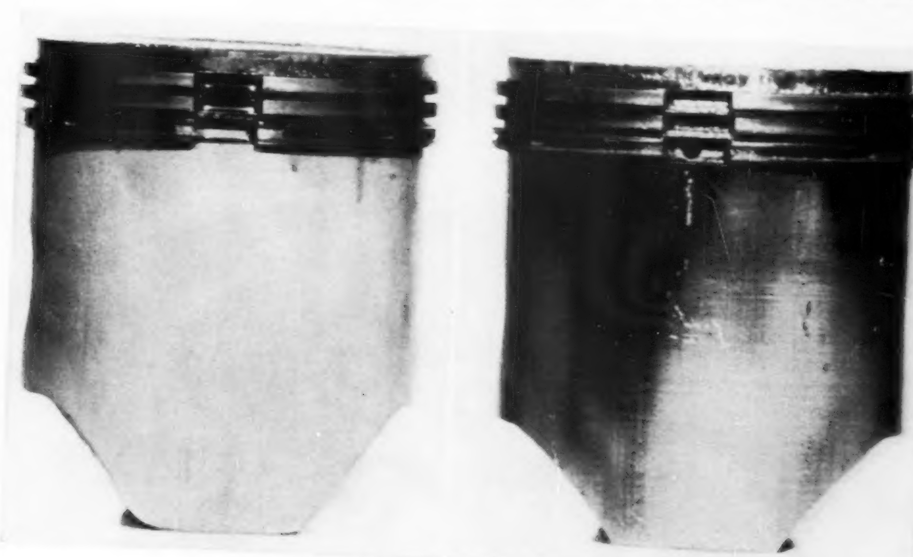


Figure 39 – Effect of oil quality on low-temperature piston deposits.

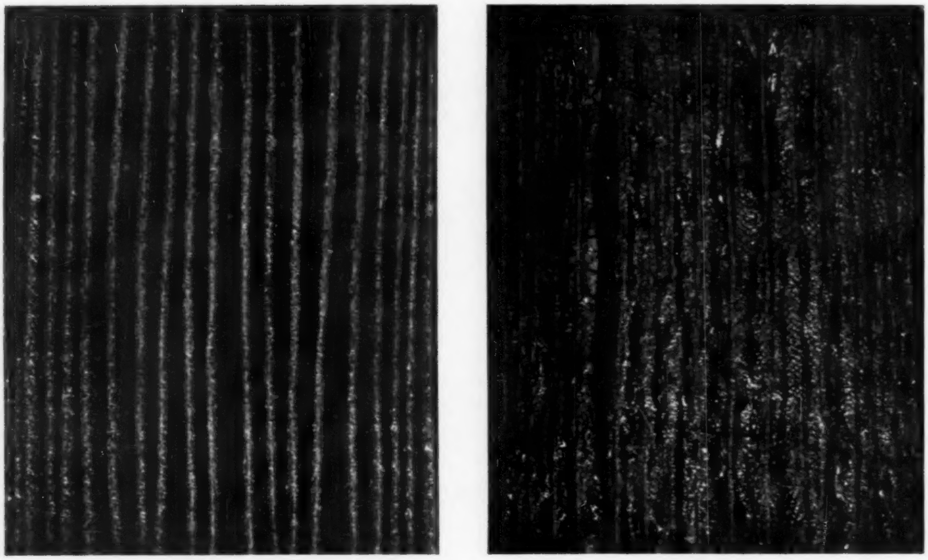


Figure 40 — Effect of oil quality on oil filter cartridge life and efficiency.

which represents what was considered to be a premium type oil only ten years ago.

While the careful selection of base stocks and additives and their balanced blending produces superior motor fuels and oils, there are occasions when engine design may produce an undesirable situation. Such a case is represented by the fouled spark plugs in Figure 41. Here, a current model V-8 engine was operated in the laboratory on a cyclic procedure consisting of both low temperature-low speed and high temperature-high speed phases. In less than 100 hours, the fouling shown was obtained. Investigation of the cause revealed that the combustion chamber design was conducive to heavy deposit accumulation in a restricted area and that unfortunately the spark plug was located in this very area. A design

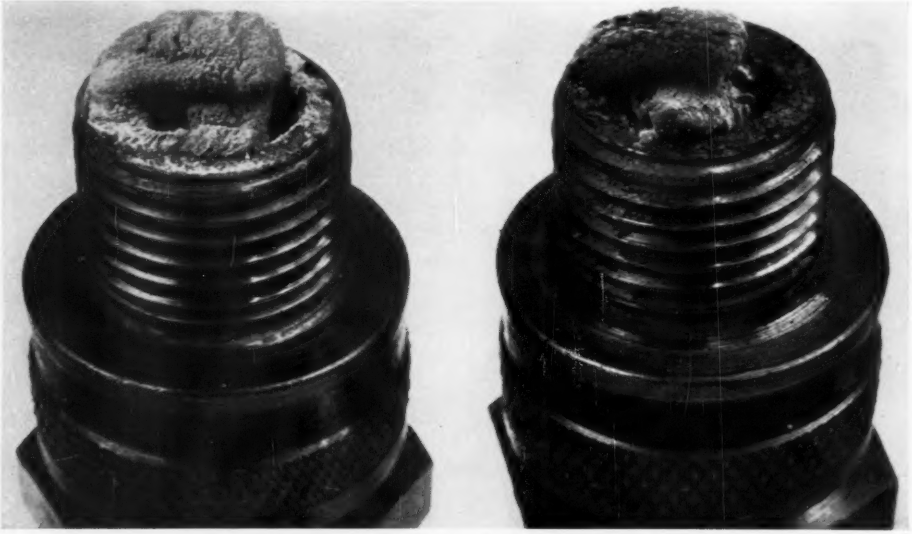


Figure 41 — Effect of spark plug location on deposit accumulation.

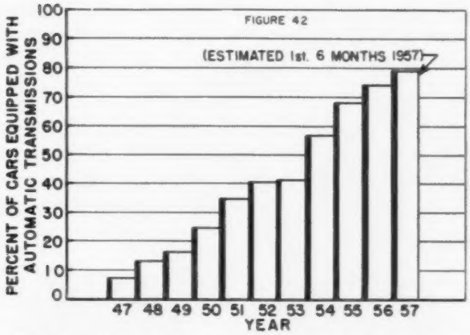


Figure 42 — Per cent of cars manufactured with automatic transmissions.

influence of this nature would be most difficult to combat with fuels and lubricants.

Transmission Fluids

Prior to World War II, the majority of passenger cars were equipped with conventional transmissions whose lubrication requirements were relatively straightforward and not severe. In the past ten years, however, this situation has changed appreciably as indicated in Figure 42 where a continuous trend toward extended use of the automatic transmission may be noted. This trend has established an entirely new set of specialized lubrication requirements. An automatic transmission fluid must act as a lubricant, a coolant, a hydraulic medium, and a power transmitting medium. It must possess good temperature characteristics to permit satisfactory functioning in a wide variety of climates, good oxidation stability to prevent the formation of excessive deposits, good anti-wear characteristics to promote long transmission life, suitable slipperiness and air rejection properties to insure smooth shifting, oxidation stability to prevent corrosion of various metallic components, compatibility with a variety of seal materials to prevent early seal deterioration and good water stability to prevent damage to the fluid additives during accidental exposure to water. While these represent a wide range of requirements for a single fluid, they have all been met and satisfied. However, as discussed earlier, there has been a continuous upward trend in the power transmitted through these units together with a consistent rise in their operating temperature. These factors have combined to periodically increase the severity of the requirements to a point where the fluids of a decade ago are unsatisfactory in today's transmissions and have been replaced by new ones to meet current demands. The next figures illustrate the progress that has occurred in the development of automatic transmission fluids. In Figure 43, views of the torus cover and valve body from an automatic transmission are shown. The components were taken from a laboratory test where the transmission was operated at 300°F for 300 hours at constant speed. On the right are shown the extremely heavy deposits obtained with a fluid which only a few years ago was entirely satisfactory for automatic transmissions. In contrast, the parts on the left indicate an almost complete absence of deposits using a fluid typical of those now available.

Due to the trend toward higher operating temperatures, previously used seals are becoming inadequate from the standpoint of embrittlement, cracking and deterioration. As a result, new seal materials are being explored and developed. However, these are not always compatible with the lubricant. At the top of Figure 44 are two seals of the type used in the transmission test described in the last paragraph. These are seals designed to give satisfactory life under high temperature transmission operation. Here

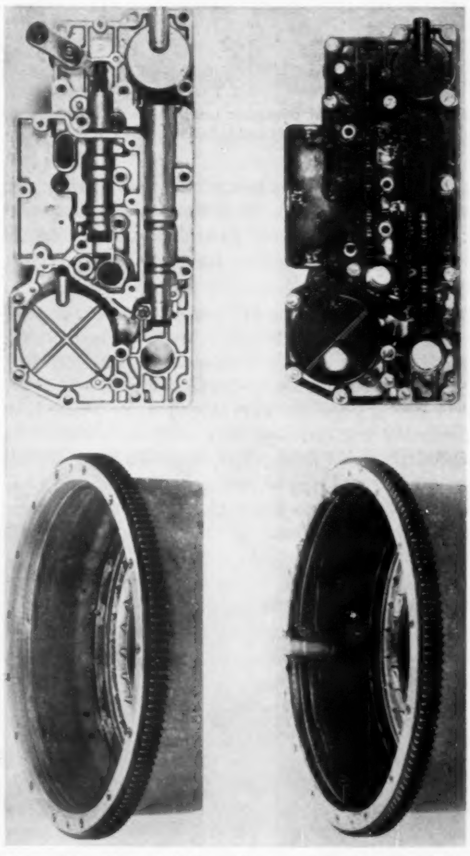


Figure 43 — Effect of fluid quality on automatic transmission cleanliness.

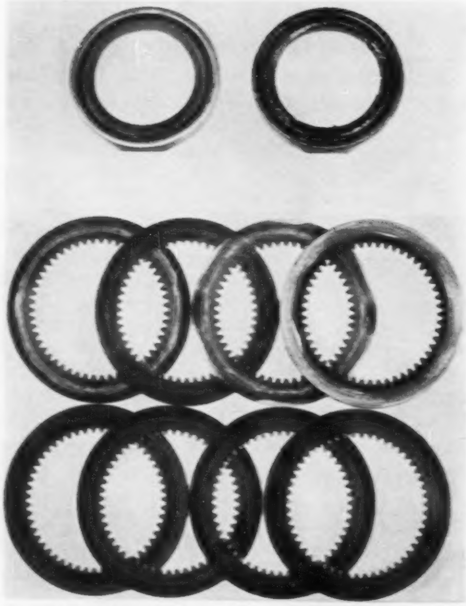


Figure 44 — Effect of automatic transmission fluid quality on oil seals and clutch plates.

again, the badly deteriorated seal on the right was obtained from a run on a fluid which was quite acceptable in the recent past while the one on the left completed the test in like-new condition with one of today's fluids.

In the lower portion of Figure 44 another requirement of increasing severity is shown. These are the plates from the clutch packs used in most transmissions and indicate the results from a poor oil (upper set) and a good oil (lower set) after a 100-hour durability test. To keep pace with the demand for increased power transmittal, there is a trend toward revision of this type of testing by the addition of an inertia flywheel to more closely approximate the operation of an actual car on the road. While it is too early yet to conclude the specific effect this revision will have on automatic transmission fluid requirements, data thus far indicate it will be another step in the direction of increased severity.

Rear Axle Lubricants

The trend noted several times earlier toward higher horsepower has also had an effect upon rear axle lubricants. While the amount of power transmitted by these units has increased considerably, their physical size has not. As a result, the lubricant has been called upon to provide improved load carrying and anti-wear characteristics. This change in requirement is demonstrated in Figure 45 where two differential or spider gear pins are shown. These were obtained from a 4½ hour accelerated car test where different size tires were used on the rear wheels to provide continuous differential action. The lubricant temperature was held at 200°F while the car was operated at low speed and high load. The pin on the right exhibits severe wear and scuffing of the metal which was obtained while using a gear lubricant typical of some of those currently sold in

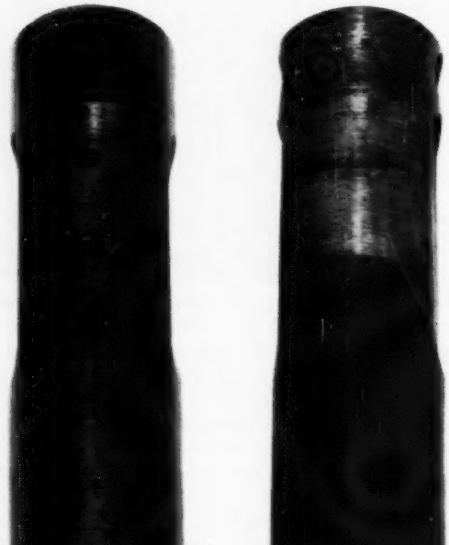


Figure 45 — Effect of lubricant quality on wear of differential gear pins.

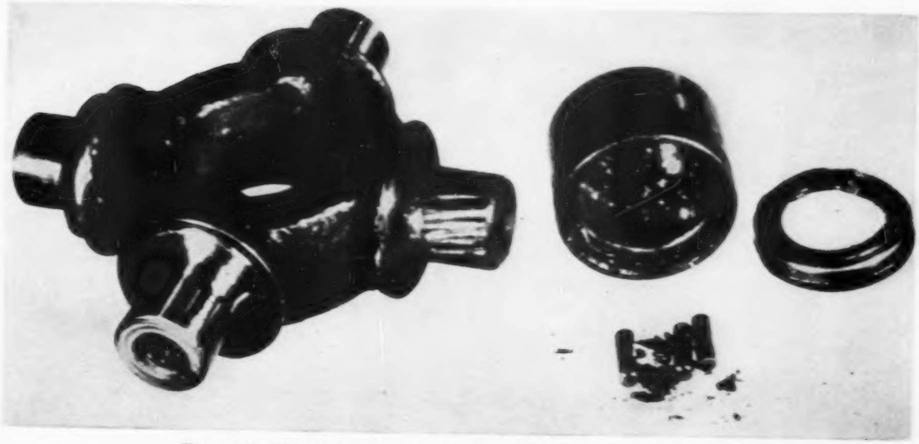


Figure 46 — Effect of inadequate lubricant quality on a universal joint.

service stations. The left pin is typical of the performance obtainable with currently available oils. In this case, there has been no scuffing and the wear has been confined to the removal of the pin's copper plating on one end.

In addition to the above, a number of versions of the non-slip rear axle are being introduced. These are relatively new units and while it appears that they may increase the demands on rear axle lubricants, insufficient information is available at this time to comment on them.

Chassis Component Lubricants

Although not a chassis component in the strict sense of the word, the universal joint has been included in this section since its lubrication requirements have generally been satisfied with a good chassis lubricant. This component is another that has been affected by the trend of rising horsepower. Its power transmission capacity has not kept pace with the rapid advances in engine output and in some cases, early failures have been experienced. One such example is given in Figure 46 where a failed joint is shown. It was obtained from a current model passenger car with an automatic transmission and a stock engine. Its failure was attributed to excessive load which broke the lubricant film and resulted in the severe fretting corrosion shown. Fortunately, other greases are available with higher load carrying and feedability characteristics to alleviate this situation.

A relative newcomer to the field of chassis lubrication is the ball joint employed in front end suspension systems. A typical joint is presented in Figure 47. At first, it appeared that this component would offer no new lubrication problems. However, as experience was gained with its use, this was proven false. It was found that normal chassis lubricants would satisfy the joint's requirements immediately after lubrication, but did not last as long

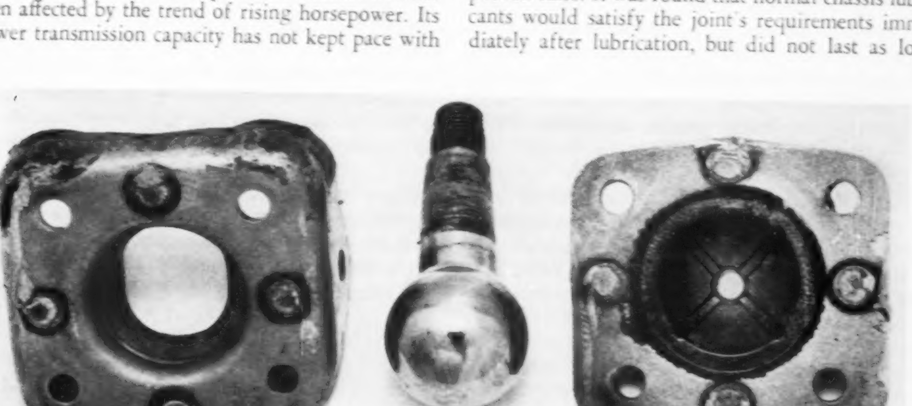


Figure 47 — Ball joint, disassembled.

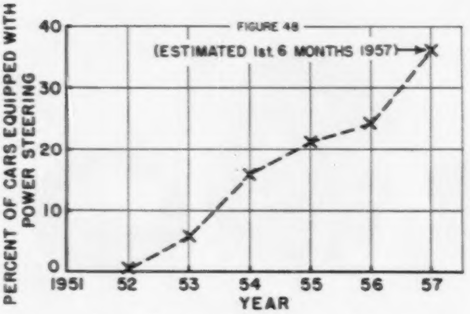


Figure 48 — Growth of power steering.

as desired. Apparently, the grease squeezed from between the ball and the socket, resulting in an increase in torque required to turn the ball and in a dry chucking noise which was audible when driving the car over rough roads. To the best of our knowledge, no failures have occurred because of this, although the noise did constitute a source of annoyance to the car owner. Design changes and greases of different composition are apparently overcoming this problem.

Accessory Lubricants

In the field of accessories only two have been of major significance to the petroleum industry. These are power steering systems and air conditioning units.

Figure 48 illustrates the increasing demand for power steering by the motoring public. It indicates that 35-40% of 1957 production has been equipped with power steering. The rapid acceptance of this new accessory has also created a demand for a lubricant to satisfy it. In this case, the product must act as a hydraulic medium and as a lubricant. It must have good-temperature-viscosity characteristics to insure ease of steering over a wide temperature range, satisfactory anti-wear properties to guarantee long equipment life, suitable air rejection properties to promote uniform steering effort under a variety of operating conditions, good oxidation stability to prevent deposition at elevated temperatures and compatibility with a variety of seal and hose materials to prevent their early deterioration. From these, it may be seen that the requirements imposed on a power steering gear fluid are similar in many respects to those of automatic transmission fluids. It is only natural, therefore, that automatic transmission fluids should be used in this application and such has been the case. However, it is not unreasonable to expect that eventually, power steering gear units will have their own separate and distinct fluid — a situation that may be caused by the increasing stringency of automatic transmission fluid requirements.

The passenger car air conditioning unit is the second new accessory to require a lubricant. Here, however, previous research and development had produced lubricants for industrial and home air conditioners which were entirely satisfactory for this application and no additional work has been required for the development of a new product.

SUMMARY

In the past decade, tremendous strides have been made in the automotive industry. These have produced a growing popularity for the V-8 engine and the automatic transmission and have introduced such new features as power steering, non-spin differentials, ball joint and torsion bar suspension and air conditioning.

Performancewise, a number of changes have occurred. Octane requirement has increased appreciably and is approaching the 100 octane number level. Full throttle brake traction has nearly doubled and has been accompanied by some improvement in brake specific fuel consumption and thermal efficiency. With the exception of certain fuel system components, operating temperatures have increased.

The foregoing passenger car trends have increased the stringency of fuel and lubricant requirements and these have been met in a number of ways. Fuels have been improved, particularly with respect to anti-knock value. Motor oils have greater wear and scuff resistance and higher detergency. Automatic transmission fluids have undergone continuous modification to improve oxidation stability, anti-wear properties and other characteristics. Rear axle lubricants have been modified to provide greater anti-wear and load carrying capacities. Where previous chassis lubricants have proven inadequate for new design components, new lubricants have been made available to satisfy the problem encountered. In the case of new accessories, lubricants have been available to meet their requirements.

The preceding discussion has shown that considerable progress has been made in the passenger car field in the past ten years and that the petroleum industry has kept pace with this progress by providing new or improved fuels and lubricants as required. This has been accomplished only through the spirit of close cooperation existing between the two industries. It is expected that automotive progress will continue at the same pace in the future and that through this same cooperative effort, further improvements in fuels and lubricants will be forthcoming to satisfy any exigencies which may arise.

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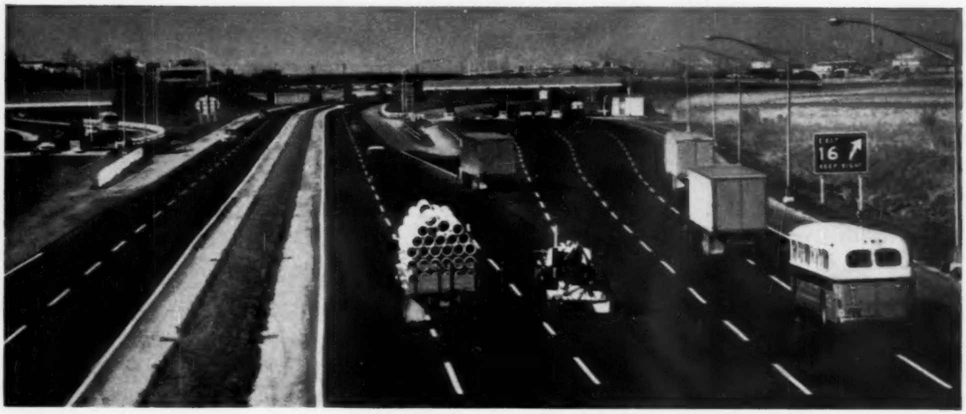

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